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THE CHARLES STARE DERFER LABORATORY, INC.
555 THOMSLOGY SQUARE
CLARESTOCK, MA 02139

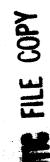
DECEMBER 1981

PINAL REPORT FOR PERIOD: SEPTEMBER 1980 - AUGUST 1981

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This report has been reviewed by the Office of Public Affairs (AND/M) and is releasable to Mational Technical Information Service (NTIN). At MYIS, it will be available to the general public, including Service matiems.

This technical report has been reviewed and is approved for publication.

LOWS E. BARRES Project Engineer

MOMALD L. RINGO

Chief, Reference Systems Branch System Aviences Division

FOR THE COMMANDER

PLANK A. SCARPINO, Apring Chief System Avionics Division Avionics Laboratory

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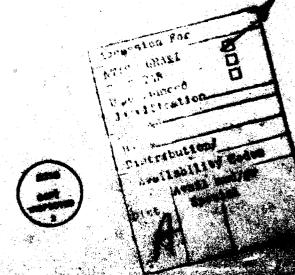
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The week seported who performed under contract no. 735625 46-54000 by the Charles Stank Sumper Laboratory, 555 Sectioology Sq., Cambridge, IQ. 02139.

The contract muniture were Mr. W. Shephard and Mr. J. Barnes APVAL/AAM. Their support and quidance is greatly appreciated.

The concept for the Low Altitude Mavigation Augmentation system
was developed by Mr. S. Joel Presselacr. Mr. Roy Murse, Mr. John Frenchia,
Dr. Howard Musoff, and Mr. Dele Landis contributed the technical data.



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The ever-increasing defense threat aircraft has made low-alitude operations in verient

The LAM utilized bearing seasurements to known impacts

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the pilot with an electronic map display on the sixtuast's BUD, point you the last to be being at make and sould so that beed down operations (locking at maps or neving mp dis altitude, mer date is presented in plays) are not required.

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In addition to the display concept, bearing measurements to known landmarks can be utilized to undere the particulation or to and also to estimate errors between the navigation syst e Riew refers noticelism isnoitingnos & mi

The concept for the LIM yes developed by CHE Anding to determine the lovest purformers; LAMA configuration. The simpletion configuration this plan, however, utilizes higher performance equipment; sino the higher performance equipment will be proposed for the 2-16 implementation: and A-10 aircraft.

erejugación as gorianis sur do presente suco estado In this report, a plan is developed to similate the little concept on an Air Force simulator. The simulation will i to verify both system performance and gilot work load under realistic flight conditions. CANAL STATE TOWN SECURIORS

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2.3 Operational Description

In a single past aircraft, operating at 100 to Shift Allen hands down operation is not possible and percently the epidents seen through the contract are dejects of justing, discussing all not the amplific planer that seen from higher whiteen that the planer that seen from higher whiteen that the planer that seen from higher whiteen that the planer that seen from higher whiteen the seen along the planer.

Differences between the display and the And will be the fill the plant of savigation data qualify:

To reduce the need for minus, map updating, the piles was a helmet moment eight to measure bearings to lenderth (or was points). These bearing measurements are utilized to update the aircraft merapator and thus to reduce the discrepancy between the singley and the real world.

2.4 Bardward Mecription

The system consists of hix sales grapehents

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The baseline is the T-16 SEM 3616 newigator. Date: Amptical systems or Radio Newigators of displac systems can also be utilized. (A model for an NEW displace analysis of the available.)

The DMAC elevation and cultural finance data black of the aircraft operating area.

The Display Generator, which selects the relevant data from the data base, transforms this data MD coordinates and selects the relevant features for MDD presentation.

The HUD where the pilot compared the disse-dissensional map presentation and the real world;

The Helmet Sight used to measure therings to selected landmarks to update the aircraft newignation information.

The Data Processor used to sile suffigures, data house and helset sight information to playing a book preferable of position and heading for the Mangay Consustant.

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The Data Processor used to mak notice of the pass and melmet sight information to reverse about a best to be position and heading for the Distance tenerator.

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newigetor possible. However, since tectical aircraft will utilize
higher quality newigetors, performance characteristics of the SEM 2416
or of a strapdown system based on the Bell II acceleranter and
Homeywell GG 1328 should be utilized in the baseline simulation.

omotech aron a markatri a 1886 ambirell theta.

3.2 Map Errors

the making of maps (including the development of the digital data) is a very manpower intensive process. Error module could be generated based on various areas of the world and based on the time when these surveys were completed.

However, in discussion with DNAC the following model was devised:

- 1) Bias between the goordinate system used by the IMS and the map assent.
- 2) Random errors in the location of individual points on the usp segment. These expers are correlated; relative errors depend on the distance between points.
- 3) There is no correlation of errors between may segments. Not all segment boundaries are known.
- 4) Maps contain point errors; especially in the cultural data basis. Now Yeatures may not exist in the data base; features are located in wring positions; summittee the features have been physically rempted from the positions and from the feat base, a basels also data land "shows

There error sources will have to be introduced into the

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3.6 Summary

The display on the MUD is insocurate due to

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- and errors in the map
 - 2) Errors in the position and heading output of the inertial asylgator and errors in the aircraft altitude readout

Carlo Carlo

The update system is inaccurate due to

- 1) Errors between the inertial and HUD coordinate frame
- 2) Errors in the pointing system

3.7 Recommended Error Model Values for the LANA Components

GYRO ERROR MODEL TERMS FOR TACTICAL AIRCRAFT GINEALIED INU

Error Designation	Error Type	Mumerical Value (10)		
Bias Drift Uncertainty	Random Constant	0.004. /h/2 22 42 2 22 42		
Bias Drift Randowness	lst-Order Herkov	0.0067 ² /h T = 20 min		
g-Sensitive IA Drift	Random Constant	0.005 ⁶ /h/g		
g ² -Sensitive Drift (Specific Porces along IA and SA)	Rendom Constant	0.005 ⁰ /b/g ²		

Note: Gyro type: gyroflex

ACCREMISETER ERROR MODEL TRANS

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Random Constant Source Source

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Size Singeries Rendon Walk and with the earliest and the (Manarical Value Not

Available)

Scale-Factor Uncertainty Random Constant

500ppm

Scale-Factor Asymmetry Random Constant

50ppm

Scale-Factor Monlinearity Random Constant

Megligibly Small

 $(5\mu g/g^2)$

IA Monorthogonality Random Constant

0.2mrad

Note: Accelerometer type: Pendulous

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Error Designation	Error Type	Numerical Value (16)
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Bias Drift Randomness	Random Walk in Drift Ingle	0.01°/√ h
Scale-Pactor Uncertainty	Random Constant	strandrá s aga ileata i secific
Scale-Factor Asymmetry	Random Constant	
Scale-Factor Monlinearity	Random Constant	5 X 10 ⁻³ ppm/ ⁸ /s
IA Monorthogonality/ Alignment Stability	Random Constant	o tugy ti <mark>l 1999</mark> tugy militar 24 (ip. Deposition to the Addega)
Quantisation	-	3.15ato/ptlat rols

Notes: (1) Gyro type: Ring Lever, HoneyWell GSE326

ACCREMOMETER EDROR HODEL TERMS FOR Error Designation REPOR TYPE Bies Uncertainty Random Constant del Introduction Pandrupage - Science of Readon-Halk , as it is Hegitable Small (Numerical Value Not Available) Scale-Pactor Uncertainty Randon Constant directart 1pg/g² Scale-Factor Nonlinearity Random Constant to a longitude of the end for yalled in A (5 IA Monorthogonality 0.05mgad Random Constant - produce a comprehensi salada ya 🐯 🖼 Nap Breck Madelak, passava za ito alawa . 1. A Location Arror of the 190 meter from the engine 5000 meter correlation distance Serp correlation in transition between map segments 1.1 人 大山,高岛西 南州山西沙岩 Helmst Sight Error Model Blas Error 4.4 A Courage Proper Commission of the 30 minute correlation time .lidogram/ams.co. ni .eigaprime random constant of SME OFF y **t**arangta "da "t Attitude System Error Model COME BUSINESS OF SOME SET OF A DEMINISTRATION OF THE PARTY OF THE PART There is an expression of the contraction of the second section of the second s Cavity Start Will be beginning worse made

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Introduction:

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At 411 facilities, the vignal simulation constituted this.

- 1) A display of the "real world" as seen from the cockpit of the aircraft
- 2) A display of the HUD presentation of the real world
- 3) The HMS reticle projected on the "real world."

Projection System Considerations

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Since it is extremely difficult to match the distortions of the three optical systems, it is recommended that the HUD display and MG reticle (cress hair) be mixed electronically in the projection system video, so that distortions introduced in the prejection system affect all displays equally.

Accuracy Requirements: 4.3

The modeling in the simulation is based on the following principle in both the display (HUD) simulation and the the measurement (HMS) system simulation:

Errors in the computed parameters are added to the "true" values to move the HUD display relative to the "real world" and measurement errors are added to the MMS reticle libeation (as defined in the video) to develop the bearing angle errors.

Thus errors in the simulation hardware have to be smaller than errors expected in the 1868 implementation.

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Constitution backers constitution to their telephones of the constitution of the const be small compared to the expected asserter of the little devigation File cockett. A 190 wartical can 190 and a started

flights between two points, such that my errors between the points are uncerelated, and relative mylentics in a line with For long flights supected system posttion underfinish to approxi-

metaly 100 metars. For SER visibility to himbulks, while errors are 20 milliand. Thus for long distance navigations

> Location of the aircraft in the real walls and to be known to approximately 20 meters.

Heading of the aircraft in the "med world" and attitude of the aircraft in the "real world" need to be intere to approximately 4 millions w. 25 degrees, or will

If the location is degraded to approximately 100 meteor or if the angular errors degrade to i degree, simulation occurs mill control the performance of the AME orning of the State year

Local navigation (for offpet aimpoint beauty to not been considered in the similating suicking on the state paint. Course intian of marges within the marginalism. mentaled with somethership quality accounty diff during t in relative notification structure ath to be subleved anoth

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5.0 Simulator Pacility Site Survey

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Williams Air Force Said State Land Bits GUE
AFWAL Pacilities in Wildy Williams Landrettory Facilities
C.S. Draper Laboratory Facilities

The Williams Are simulators are not typical operational typical simulators. They are in dant, making beat research simulators that are presently configured with an Ir-10 and an Ir-16 cockpit. A 150° vertical and 300° azimuthal autholds (computer generated) scene is provided for each cockpit.

puters with Singer-Link softman to generate an autoids some, and SEL 12-75 computers for plantium operations. A 2 to 2 tile target area in the only erene stilining the digital fill lendence systems (DEME) data been. This data been mill have to be outsiderably expended to accommodate the LAMA requirements. However, with the additional data been the Williams AFB facilities remain a viable option for simulating a total Low Altitude Savigation Adjustration (LAMA) System. Educating the Vita and demonstrations does not appear to be an issue) in Mart, the phreomet were recuptive to delicating experimental operations in Williams AFB facilities and expension program which; thus completed in a 14-4-years beach, any enable them to accommodate the fall escale administration of the

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The negative aspect of the terrain belt is that a data base does not emist for it and, without life has been during with the task of providing work a data base the thestine is deciding. In addition, both the F-15 and the F-16 are, at the task life ted in the size of the outside scene that on he atick medica.

The C.S. Draper facility can also be used for the interesting lation. A considerable software affort will be required to produce a useable LANA simulator at this facility. After this investment it will do no more than the F-15 simulator in Building All against that simulator time scheduling at the Draper Secility will affor no problem.

The Flight Control Development Laboratory had a 18.5 % \$7.5 mile terrain board with a TV probe and several cookpit configurations. The topographical (DMA type) data base is now smallable. A cultural (DMA type) data base will be developed for the beard starting in CY1981. The board can be "overflown" several times in both directions to provide the required flight times.

An extensive hybrid computing facility is available at the laboratory. Upgrading of the computational facility is now in process. Accuracy of the TV probe system is close enough to the LANA requirement to make use of this facility feasible.

The laboratory staff has shown considerable interest in the LANA concept and is interested in supporting the simulation program.

Based on the everyor, the Flight Control Devalquest inhumetory has been used as the beseline for the detailed simulation fluglorment plan.

Figure 6.4 shows eductions of the return rate of the responsion of the servery should be notherwhile as displaying the responsion of the responsibility and the responsibility an

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The TV-comman ignoral problem will be specially administed as the base from the special weight as the position within the system. The problem to the will be will be williaged as the true alrerest heading and true alrerest actions.

merigation expose.

Similarly attitude errors will be added to the camera attitude to generate the MVD LGS errors.

However, due to the complexity of the simulation, it is recommended that the simulation be developed in steps. Using this approach, the amjority of the coding can be done off line. Thus, abbugging of the code and running time of the various modules can be calculated while the simulator is used for the support of other programs. Figure 6.2 represents the first step in the simulation.

First a representative flight path will be flown across the terrain board and recorded for further use. This flight path will be utilised as the baseline for simulation development.

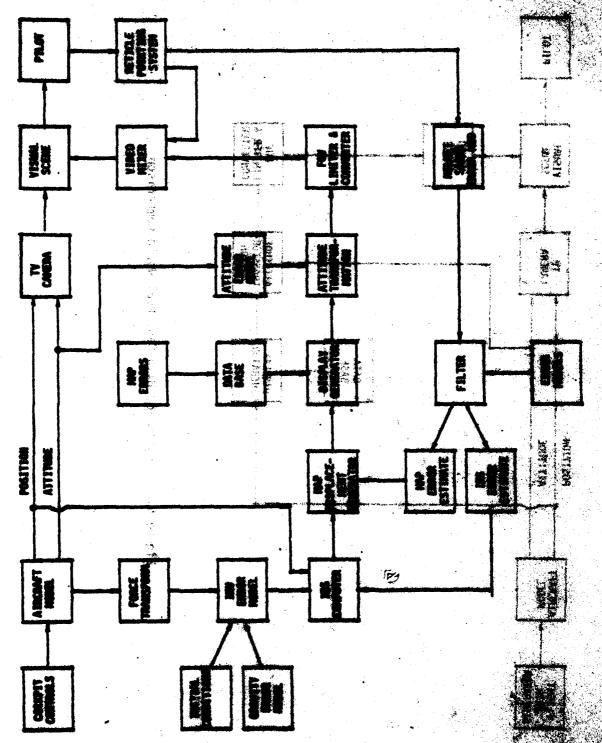
an Brada all' libble da unionesa

A NUD presentation of the flight path can now be developed off line utilizing software developed at CSDL or modifications of software developed under the Air Force's electronic map program.

Differences between the RUD and visual display should only be due to errors within the data base. These errors can then be removed or additional errors can be added to make the data base "more realistic."

The next recommended configuration is shown in Figure 6.3. This configuration will be used to gather pointing error statistics from the similated Scient monitor sight. The data will be welliated in the MMS error model used in the complete Similation.

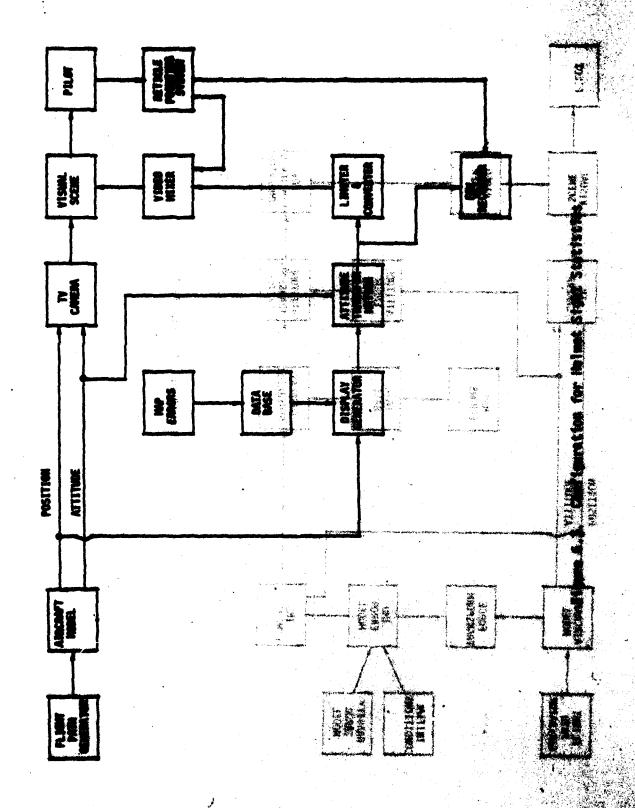
Figure 6.4 shows addition of the IMU, altitude, and data base error models. The errors should be noticeable as displacements between the visual display and the MUD. It is resummended that these errors be added sequentially and that each model be evaluated segurately:



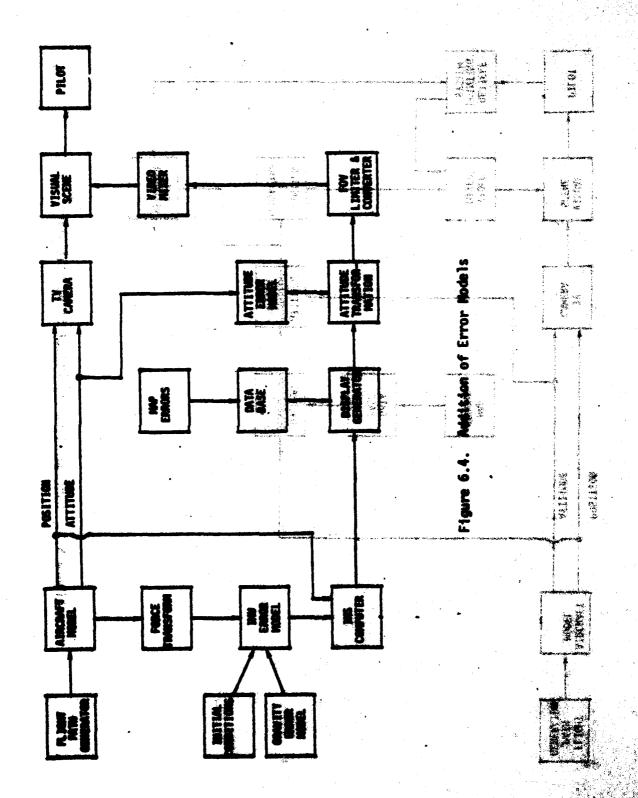
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France 6.1. Black Diagram of Complete Simulation

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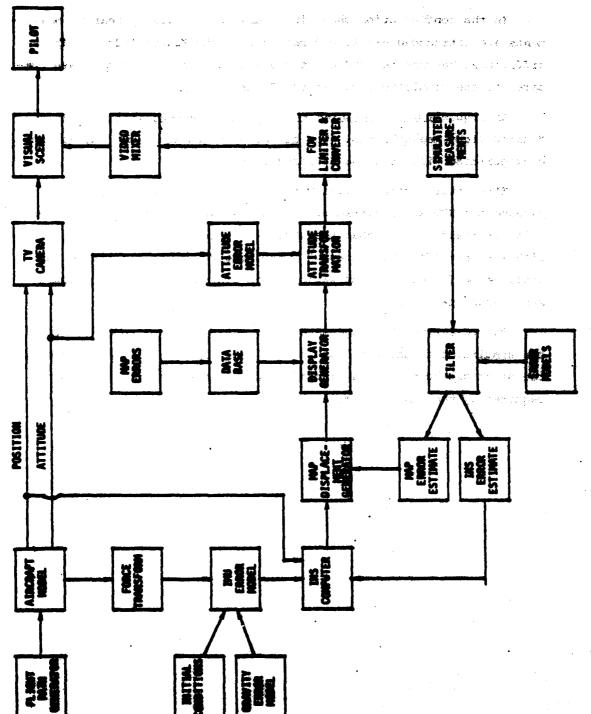


Figure 6.5. Navigation Filter Operation Assessment

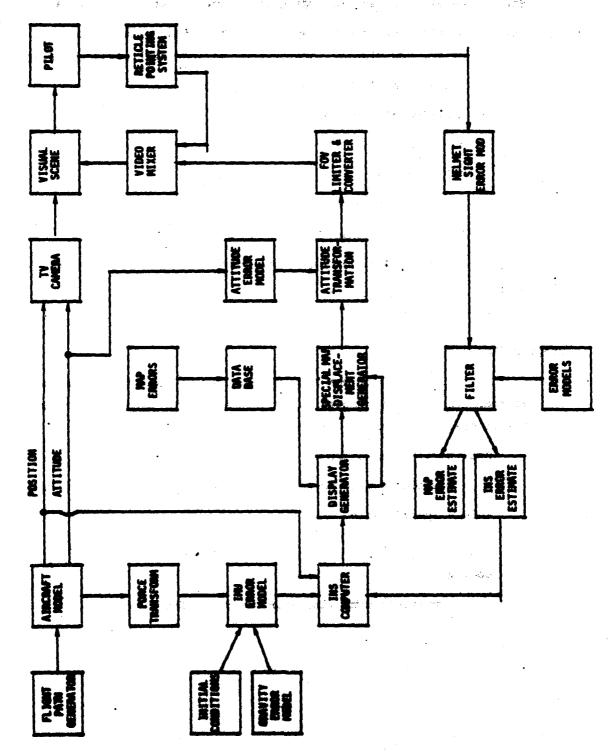


Figure 6.6. Addition of Actual Measurements

Sumary

- Step 1 Development and recording of a representative flight path
- Step 2 Development of HUD display for the flight meth, similation of the HUD display superimposed on the "Mill world" display
- Step 3 Collection of BMS pointing statistics
- Step 4 Addition of error models
 - 4a) INU
 - (b) Attitude
 - 4c) Map data base
- Step 5 Addition of Kalman Filter with simulated measurements
- Step 6 Replacement of simulated measurements with real measurements
- Step 7 Full simulation

Program Blements

A modular approach has been recommided as the primary technical approach to the LANA simplestion development. For each of the modules six general tasks can be defined:

--- Analytical Formulation --

Module Specification

input output format, running time, memory requirements

compatible with simulator compating theility



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7.1 Punctional Specification

True position, arisolty, ettitude, attitude at a reconst

computing facilities everyther in a restrict of the second of the second

aircraft controls (stick and through) to "figure a "V projection" terrain board or alternately a puersconded path can be repeatedly "flown" over the same board. A picture of the board, seen through the TV probe is presented to the pilot on a TV projection system.

The LANA simulation will written the first data data base of the board and superimpose on the TV display an abstract (ridges and essential cultural features) of the data base information simulating the display presented on the aircraft's BUD.*

The HUD display will be displaced relative to the TV probe display due to errors in the simulated aircraft navigation and attitude determination system.

A reticle will also be superisposed on the TV probe scene. The location of this reticle will be determined through a Helmet Mounted Sight measurement system in the simulator cockpit and on the helmet worn by the pilot/operator.

Bearing measurements under by the pilot/operator utilizing this simulated HMS will be used to update the simulated navigation system.

Defore each flight it will be possible to select error models for the various system compensate. We the diff of the flight hard copy seconds of system partformages will be provided.

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Inputs during eigulation run:

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Helmet Mounted Right reticle bearing is chimined from the ms readout system in the circulation endpit. He was took of any part

A "bearing mark" input is provided as a switch closure on the stick of the simulator cockpit. He was to be an entire absorbed

> An abort command is available in the cockpit. The second of th Simulated HUD display is available from the display generator.

Inoute before simulation Plate and the feet with

Values for error coefficients for the Link components; or alternately a code selecting a specific component error model.

> i ent wiitazarin tita The MMC data base modified with TBD map errors.

> Operator/Filot identification.

Plicht path type identification. The gradule recommends base

Marretive 300 need in output heading.

Imputs after simulation run:

Compute and print hard gopy. A 50 stew social bear re this

Reset and store data or reinitialize and change parameters.

Outputs during simulation run:

Simulated HUD display to video sixer.

Similated seticle to wife mise, papers of an alabor Betimeted position and heading to the display generalise. Abort indication during run.

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Manuative 200 weed to Admitity was include tellering to the section of the section Flight path type,

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7.2 Timing Requirements

17.2.1 . Introduction when the assemble light athirt and agence

computationally the most difficult part of the shadowith is the generation of the simulated MD display. It has not been determined whether, smooth motion of this display de magnised from a human factor standpoints homeomy, the display washing, while utilizes the DM data base (spier contract by AFMAL/NA) will equate at TV operatible rates. Thus, smooth motion of the classical MD is possible and will be utilized as a baseline in this simulated development plan.

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7.2.2 Requirements for individual modules: Tolly Normand

Force Transformation

Partiffer amplementation

displayed a will be ablesationed.

INU Error Model

CANDAL MAD CONTINUE APE.

Gravity Error Model

The time stage have to be sufficiently short to keep subtific forces approximately constant during the time steps. Non-real time simulations have shown that for ~ 2g turns 30 sec time intervals are sufficient. However, if tighter turns appear appropriate in the flight simulation, shorter intervals will be required. It is important to use the average specific force during the time interval and not to sample the specific force at the time of the update.

IMS Computer.

In this module the May system error is added to the "true" position. The output has to be compatible with the display generator. Thus, every 1/30 sec true position has to be read, errors added to it to provide an output every 1/30 mat. (Mats errors things only every 30 sec.) ் (1 1 1 1 1 1 **நீர**் முறுகை **ந**ாழ்**க**ள் இது முதுமையி

MAP Displacement Generator.

In this module, the addition is also performed in 1/30 sec though the filter input changes very slowly. (It is recommended that this module be included in the INS module to reduce computational delay.)

Display Generator and Data Base.

These computational elements are under development. Inguts are required every 1/30 sec. Outputs are provided every 1/30 sec.

Actitude Transferention Middle of to colderency was al this module vill be available as much of the Display Substator models. Resident the back to be be because the best of the best of

Mctitude Error Holel.

the exters though slowly large land online at the unities of the bus of the or output have to be TV compatible (1/30 sec). derelopment plan.

FOY Limiter and Converter.

This mobile converts from digital date to disting many the video sime. Since the indocuntion is I but the additi viduo or white securation; the D to A dis ble exerction is required.

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This module reads the Belmet Sight and adds black satura to the video at the reticle location. TV competible operation is required. suportional Raquirements

Helmet Sight Error Model.

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Estimates need to be propagated at the error update rate (30 sec/step). State variables are recomputed after every measurement sequence (5 to TO Godel westigal, intel congr 10 min intervals).

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This module reads the Reimst Sight and adds minot varuation to the video at the retrois location. We comparable operation is required.

Helmet Sight Error Model.

The NG error model needs consideration at the NG legation in the NG case coordinate system to generate the gyro "g" sensitive drift terms and the accelerometer bias and scale factor error.

Inputs: Aircraft CG acceleration

Aircraft Attitude rates

In local vertical, north coordinates

Outputs: Acceleration of the IMU outer case

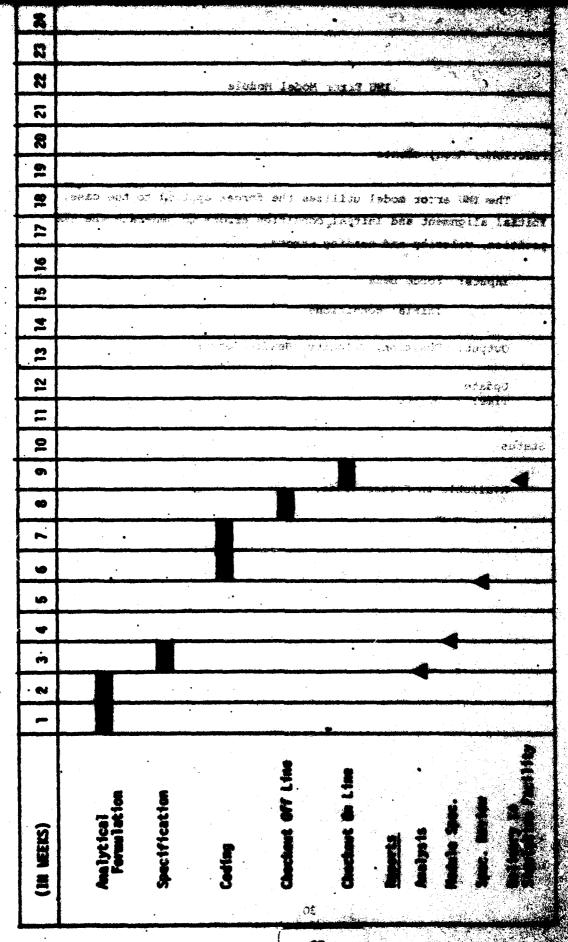
Rotation rate of the IMU outer case

Update Time: ≈ 30 sec

Status

This is a new module. Analytical formulation and coding has to be performed. The coordinate transformations are simple. No major analytical work is required.

FORCE TRANSFORMATION MODULE DEVELOPMENT PLAN



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INU ERROR MODEL MODULE
DEVELOPMENT PLAN

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Map Displacement Generator

Punctional Requirements

The Map Displacement Generator utilizes the output of the INS computer and adds to the INS computed location the estimated error between the INS coordinate system and the Map coordinate system as needed by the Display Generator.

Inputs: Inertial Position, Heading

IMS Map coordinate system error estimate

Outputs: Estimated Position in Map coordinates

Aircraft Heading in Map coordinates

Update

Time: 1/30 sec

Status

This is a new module. Analytical formulation and coding has to be performed. He major analytical work is required.

May Active

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MAP DISPLACEMENT GENERATOR MODULE DEVELOPMENT PLAN

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DISPLAY GENERATOR MODULE

DEVELOPMENT PLAN

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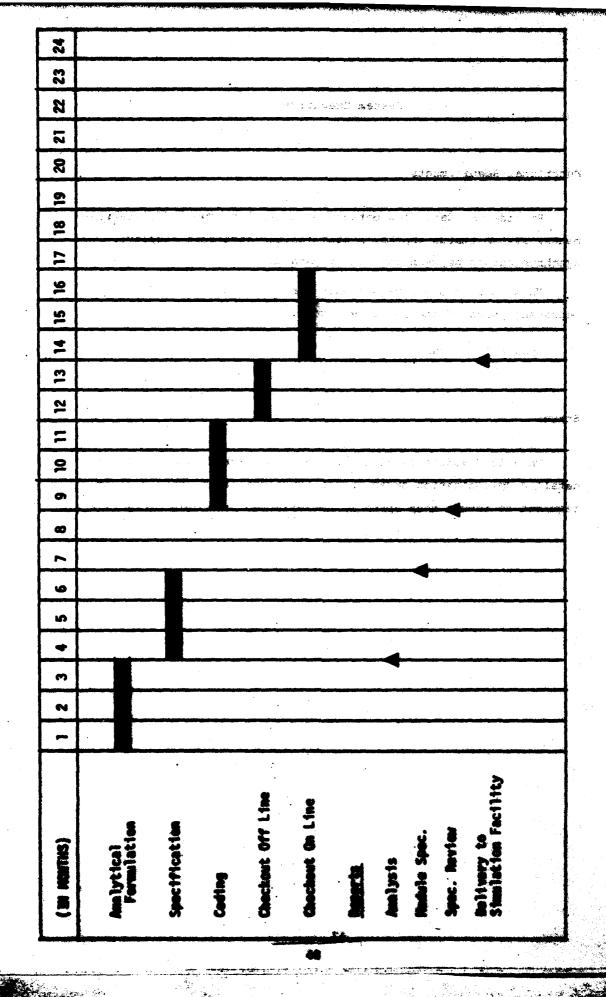
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SYSTEM EXECUTIVE DEVELOPMENT PLAN



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Special Map Displacement Generator . Development Plan

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The ground 1800 configuration represents a first star is the religional of the DEEC data base for navigation system updates. The system is in the parties form is designed for daytime operation.

For night time operation, a FLIR can provide the real recit display in the aircraft cockpit. The pilot can still use the below sight to paint at a landmark (shown on the FLIR display) and update the inertial nevigator as is proposed in the daytime configuration.

For adverse weather operation (in a two seater configuration) the second crew member can use a SLR as the primary navigation sensor and compare the SLR image with the DNAC generated view (looking to the side of the Flight path) while the pilot views a data base generated image of the world as authorit front of the aircraft.

In areas with large elevation changes, clues can be provided to the pilot showing potential exits or warning the pilot about areas where rapid elevation changes exceed the performance of his aircraft.

Real time changes in the cultural data base of a given operating each can also add to the effectiveness of the system; especially addition with threats. This addition would allow crews to avoid known high threat agass when these crews are assigned targets beyond these areas.

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APPENDIX A serious cash and becaused as 240 siv besitatoral at a serious of the cash bas from serious as summer of the cash between Laboratory Widor 1979 Into Project 110 Cash and instantion of the LANA concept.

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The inertial system error model uses 17 states and was electrical from "Imergial Newigation System Error Models" by W. Widness and P. Grundy, TR-03-73, May 1973 Intermetrics, Inc. Since the Statestions were only to a first order, no attempt was under to introduce applie factor errors or graneitive turns into the improvement of the model. Consequently, a benton environment and appropriate value over for the case of a straphone family and the the terms of the case of a straphone family.

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to be inttialized via GPS as determined from data quapital Articles in some of the runs for LC105, a 17-for initial drift and a 7-or initialization of the runs for LC105, a 17-for initial drift and a 7-or initialization of the runs for LC105, a 17-for initialization of the runs for the last tensor of the last tensor in the last tensor

For either the high performance or LERS cases, switting errors are deminated by the map errors. The utility of the Middle William C. arrangement is the residence manifested by a springeric space of right the imprison antiquent to appear to accomplish arrangement in the residence to a second to make property to a second from the second from the man cases he made rather than the confished with of position arrangement the specific particles arrangement to a second for LCIOS comming below 100 ft. Lo for about a plance of position arrangement in the second for LCIOS comming below 100 ft. Lo for about a plance of position arrangement and for LCIOS comming below 100 ft. Lo for about a plance of the position arrangement.

extended Kalman filter. The actuel line of Suntains of buttons A extended Kalman filter. The actuel line of Suntains of buttons of the button of specified by an aximuch and elevetion angle of the filter to the extended to the section of the secti

2.0 SIGNARY OF SIMULATION RESULTS

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When an faith at give drift error of 10/hr is introduced into the interception of the confidence of th

errors when using from Imports, for example, a two made for the with 20 evenly special partners over a 200 second period results from herizontal position errors before and after measurements at the last landmark of 87.3 and 67.6 meters respectively, which roughly correspond to high performance system errors using only 9 landmarks.

LCIES horizontal velocity errors were never inter them A files 0.6 although for a support of cases the errors were close to 1 for 50 concress, the lates springers against hed policity errors as like as concress, the lates springers against hed policity errors as like as 0.6 fps.

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LC100-14 frace of the manufacture white reduced to the state of the control of the optical measurements on 11 evenly spaced landoutle manufacture period of less than 1500 seconds are offerting in principal and the enterior of the following this callings of the principal and the compact that callings are sent to the high performance system position errors at the compact the enterior of the performance system position errors at the compact the enterior of the performance system position errors at the compact that the compact the enterior of the enterior of the compact that the control of the compact than the compact that the control of the contr

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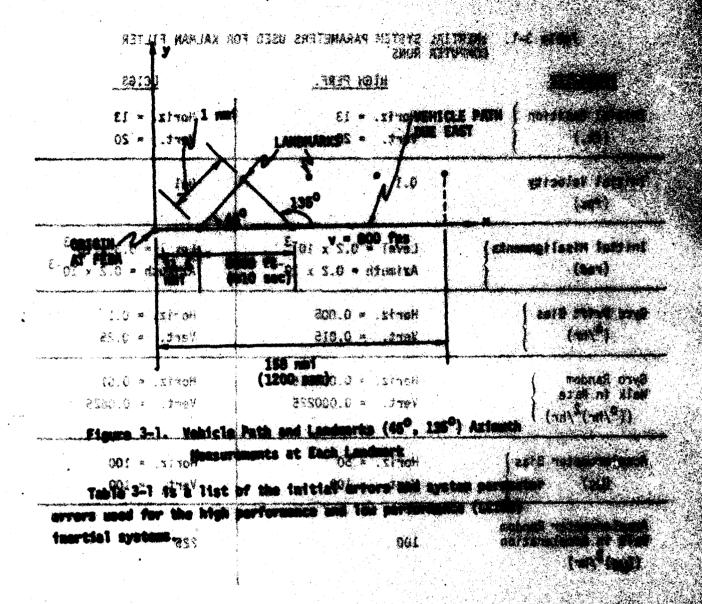
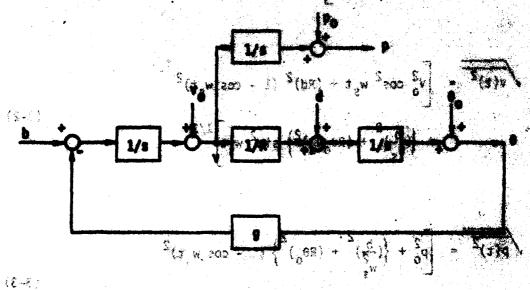


Table 3-1. INERTI	al system parameters used f er runs	OR KALMIN PLTEN
PARAMETER	NIGH PERF.	
	Hallertz. • 13 Biggert. • 20 Harringhal	Tim (Hards: • 13 Virt. • 20
Initial Velocity (fps)	0.1	* ;
Initial Misalignments (red)	Level = 0.2 x 10 ⁻³ Azimuth = 0.2 x 10 ^{-3†} 00	Alfan . Market.
Gyro Brift Bias (°/hr)	Horiz. = 0.006 Vert. = 0.015	Horiz 0.1 Yert 0.25
Gyro Random Walk in Rate ((⁰ /hr) ² /hr)	Horiz. = 0.00001(005) Vert. = 0.000225	Horiz G.Gl Vert 0.0625
Accoloremeter Blas (48) ************************************	norte e faction de sans	Turnshorts 10 correction (2:50)
Accelerance Random Nalk in Acceleration ((Mg) ² /hr)	160	o note and not been violen 2000 Ematerya (stange)

For both systems, inoutial system corners to the effective system ortical manufacturing plants the plants of the system the barriers and a system used. The barriers of the extension in particles, valuably, and size ignorant days the suspects of the standard Schuler loop presented in Figure 3-2.



b = accelerameter blas, n/s R = acres rets.

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For both sectors inertial system enters in the character operated and for the contest operated and the contest of the particle inertial system model aquetions used. The horizontal enters in position, velocity, and misalignmentage the outputs of the contest spiniter toop presented in Figure 2-2.

$$v(t)^2 = v_0^2 \cos^2 w_1 t + (Nd)^2 (1 - \cos w_1 t)^2$$

$$(3-2)$$

$$p_0^2 + \left((\frac{1}{2}) + (N_0)^2\right)^2 (1 - \cos w_1 t)^2$$

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$$p_0^2 +$$

Northcotal errors for the high preference spring were destrated by the effects of the initial meal ignimat angles assumed for the horizontal axes. The Schuler escillation tended at first to reduce dis initially should still the still should be supply offects of the initial meal through the should should be supply gare drift term was sufficiently large to cause the administration. Should server to increase significantly with thus return this, to decrease as in the high performance system.

The vertical classed porttion error use desput to the estimate bles. Market velocity origin based in the entry and in.

Table 3-2 lists the inertial system position equate at each landmark before and after the optical measurements are incorporated. Corresponding velocity errors are listed in Table 3-3. The propagation of the high performance system errors between landmarks is "driven" mainly by the micelignment error. Because the gyro drift is low, the horizontal miselignment angles are rapidly reduced by the filter with no propagation of miselignment error between measurements until the affects of the random walk in gyro drift become large enough relative to the reduced miselignment error. In the case of LCISS, there is a strong initial driver of miselignment angle between measurements due to the large gyro drift.

The use of more evenly spaced landmarks within the 20 minute interval obviously results in less inertial system error propagation between the more closely speced landmarks. Runs were made with 9 evenly speced landmarks for the high performance system and LCIGS. The position errors and velocity errors just before and after the measurements at each landmark are listed in Tables 344 and 365. Heal Comparison with the 5 landmark case (Tables 3-2 and 3-3) shows a considerable levering of errors. Errors immediately after a set of measurements are still degrinated by a priori may error but do show a 405 reduction from the 100 meter map position error at the 9th landmark for the high performance system and a corresponding 23% reduction for LCIBS. Velocity errors for the high performance system are below I fos in the target area for either 5 or 9 landmarks. LCIES velocity error while reduced when 9 landmarks are used is still considerably above. 2 fps. [1.e., 2 fps before measurements, 1.3 fpc after measurements, at the 9th landmark.]

All of the above runs for LCSGS essented a midest initial gare drift for LCIGS (*3°/hr herizontal drift, 0,255/hr vertigal drift). It was desired to see the effect of a much larger lifttal gare drift, 1°/hr, essuming no GPS calibration for drift. The optical measurements were for 19 evenly spaced landmarks as previously, but over a time interval of 2400 seconds so that the FEBA line was assumed to be traversed at 1200 seconds. Thus about 10 landmarks were in effect used to "pre-calibrate" the LCIGS with the 1°/hr initial drift during the first 1800

Table 3-2, INERTIAL SYSTEM POSITION ERRORS WITH KALDON FILTER

andrine (dose	High Performance System Performance (Messes)	LCIGS Position
jelumetarius. Landingel	A company of the comp	bad was onen g va
1 641 K. A.		87.3 PARTIES
2	148.6	15. 12. 256. A 20110 2000 (0.0 A)
a ra si sai ra	182.1	earth 288.2 towns for 87.3
	143.6 81.4	231.8 90.0
5	124.3	850 ng 245,5 plan 1090 99,0
	Above from Fig. 4	Above from Fig. 16

កា ទៅ ១៩ ខេត្ត ឧសាស ខេត្ត ១៩ ខេត្ត ព្រះពី ស្រាស់ 15 ខែការ ខេត្ត ខេត

Table 3-3. INERTIAL SYSTEM VELOCITY ERRORS HITH KALMAN FILTER

	High Perform Velocity Em	mance System rors (m/s)	LCIES Well Errors (m	kifty is Waxasi
Landmark	Sefore Hoes.	After Ness.	Before Mess.	After Mess.
1	0.47	0.41	11.71.7 0.73	₹ 70.58
2	0.77	0.35		0.43
3 - 1 - 22	0.48	, To, per 0.23 6 g. 190	9.46	0.49
4	0.31	0.18	[Figure 1 at	9.57
Tariff Harrison	0.29	0.23	Trina Role man	1 A 0.49
	Above fro	# P19.06	tos (Moverillian)	FQ_(3,001/0)

desired to see the created a much operation of asseming no GPS calibrated to drift. The spite of a control of the control of speciments as previously, and a control of 2800 seconds the the time time were assumed to control the total and the control of the contr

Table 3-4. INERTIAL SYSTEM POSITION ERRORS - 9 ENGINEER

•	High Perfor	rmance System rrors (meters)	LCIGS Pos Errors (m	
Landmark	Before Meas.	After Meas.	Before Heas.	After Nees.
	€ 2 56.3 0 ye	49.8	83,2	67.7
· [2 (5)] [[数 33]	106.1	22.40.72.3	141.3	4.3
A 3 (192 - 1 12)	182.0	75.5	139.4	79.4
4 ************************************	412.5	73.9	127.7	77.4
5	109.3	.69.9	125.8	77.4
6	91,6	65.9	129.7	75.4
7	85.2	64.3	135.5	300 A 81.3
8	80.4	62.7	135.5	0370/1779#4
9	80.4	62.7	131.6	77.4
	Above fro	om Fig. 25	Above from	Fig. 29

Table 3-5. INERTIAL SYSTEM VELOCITY ERRORS - 9 LANDMARKS

	High Perform Velocity Erro	ence System ors (M/s)	LCIGS Vel Envers (s	lecity vs)
Landmerk	Before Meas.	After Meas.	Before Meas.	After Meas.
1	.46			.57
2	. 58	.4	.85	.48
3	.5	.31	.66	.42
4	.37	20 . 26	ar ja šl iky bys	
5	.27	.49 ()		
6	.23	n, i o o i.U esse no	3. 30.3 35. 3	
7	.21	1000 《色 》(新聞歌機多名)(8	A so on	
8	.22	18 - 28 TO AND THE		N 2022 A
9	.28	s eram ali ndia L	7 240+ -66 240-6	
	Aboye from	Fig. 25	Above Free	

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k	tses solul Errors (ce	279238 270	Western Crr	
7 4 7 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4	Before Mass.	1977A Ten	ertotus?	Length

seconds. In all of the applicable bins, an approximate standy-state; condition to reached in about 1600 because for the dis horizontal navigation channels. There is a slight exametry between the results for the borizontal channels which is due to the optical azideth measurement angles not being exactly 45°, and 135°.

A more realistic but for from optimum choice of azimuth angles was chosen to be the set 20°, 30° with the geometry depicted in Figure 3-3.

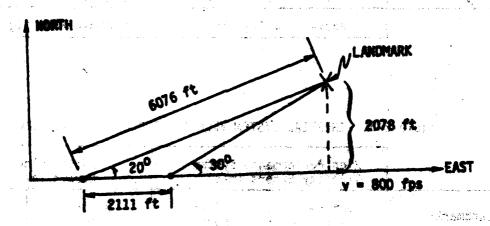


Figure 3-3. Measurement Geometry for 20°, 30° Azimuth Angle Set.

Position and velocity errors just before and right after the measurements made at each landmark are listed in Tables 3-6 and 3-7; respectively. East position and velocity errors are higher than the morth errors because of the asymmetry in measurement coefficients due to the 20°, 30° set which does not occur with the ideal do. 130° out. Both the morth and east position errors are higher than in the ideal 3-2 and 3-3. Here, unlike the ideal case mornisms measurements per landmark and/or better choice of measurement generary help in reducing the errors, but in any event, errors are not better then in the ideal case.

Table 3-6. High represented system reserved them.

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	On AND SEX			
in the beta in Officer of		total net den in	in the soults t	
2	188.8	162.7	C. W. Souel's	· Aller
	19 (197 <mark>4) (1</mark> 874) (1974) (1974)			rusta.
5		7 90 18 8 8m s		10 to

Table 3-7. VELOCITY ERRORS CORRESPONDING TO POSITION ERRORS IN TABLE 3-6

Landmerk	East Velocity Error (Meters/s)		North Velocity Error (Meters/s)	
	Before Heas .	After Meas.	Before Heas	After Ress.
1	0.45	0.43	0.46	0.45
2	0.86	0.62	0.79	0.41
. 3	0.88	0.51	0.57	0.29
4	0.62	0.36	0.36	0.23
5	0.44	0.31	6.32	0.80

TABLE SYSTEM POSITION ERRORS, S MRAG MEASURIMENT SHAME, 20°, 30° SET OF AZINUTH ANGLES

formack system for serious combinations of science spaces. States the property of the property of the states of the serious per language and measurages noise. Our period of the large serious for applies of the large and serious solutions for 45° 135° these there is ineignalificant change in error when the 5 per noise is reduced to large there is a significant reduction in errors when 3 measurages are landwark are used for the case of mon-ideal azimuth angles that are constrained to be less than 45° . Also, the further apart in value the azimuth angles are, the smaller the resulting errors.

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Table 3-8. HIGH PERFORMANCE SYSTEM - 5 LANGUAGE AND ASSESSMENT AND ASSESSMENT WITH THE PROPERTY AND ASSESSMENT WITH

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East (1	trajektos inė s vi apt. noitical apt. nort		en order and to so		(m/sec)			
% <u>\$</u>	Before	After	Before	After	Sefore	After		
10 ⁰ , 30 ⁰	1 60.7	200 (576) 97	128.6	.⊌t∄ 163 80.4	utilited bis Mo or			.33
10°, 30°	155.6	্ৰাই ^{কি} ং ু ু 95.4 াহ			d landwar e wh ee th	im. 20 t 2	71 20 210	
10 ⁰ , 20 ⁰ , 30 ⁰ 5 mr	122	100.7	New York (1986) Authorities for	2 35 (a)	TAGES TON			.22
10°, 30°, 42°	, 120	87.9	124.3	ed in Spico	28 C 28 20 11	77 - 87 - 4	errors. 	.23
10°, 42°	138	**************************************	126.4	RTHORN R	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1			.23
20°, 30°	285.3	176.8	168.6	106.9	s estimate		*	.0
20°, 30°	261.3	180.8	168.6	1985	* 45 . 6 4 7 8	T G		
460, 136	120000	75	1200 y 1771 12000 me	ne see an	*	I .	1 6	

gation of gridance system errors. The orderes assumes an error tracas, to noted as as of first-order linear times rate of the second course the state of the noise, together with linear error and some course of the noise.

TO MOITAIRAY - CHAMBEL I TO THE STATE OF MEASUREMENTS

APPENDEX B

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Draper Laboratory developed as extensive polytome stadistics (1).

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The rep	id error					77.4×30. 2	oc . %s . %	
ors.				ar to spin. It	20.00		10 ² , 30 ² , 42 ³	
pen these	two cas	ses are	ej ight,	since the	nev get	errors, gra	100, 42	
- ,		A 100 A 100 A	` {	nas surement	t is made		20 ⁰ . 30 ⁰ 5 wh	
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This makes	morandu lange st	as let lo	n progn		the Cri			
	tings and afficient the representation these dispending end the covalism t	tings are made with affireft. The rapid error sty anemaly model was. Two sets of runs sainties and 10 mm sets of runs sainties and 10 mm seen these two cardinately 2 mine over the covered and a since the covered and a si	tings are made when the affireft. The rapid error growth sty anamaly model utilizers. Two sets of runs were continues and 10 meter land meet land these two cases are dry and since the errors proximately 2 minutes aft. Overall Program Dasch Latroduction This memorandum presente covered and a since since and a since the covered and a since a sinc	tings are made when the landbar afferent. The rapid error growth after a sty anomaly model utilized and was. Two sets of runs were complete ainties and 10 meter landwark when these two cases are slighted and roximately 2 minutes after the growinately 2 minutes after the distribution. This memorandum presents a she coverfunction program.	The rapid error growth after each measured and also due to a sets of runs were completed utilizing annually model utilized and also due to as. Two sets of runs were completed utilizing aintles and 10 meter landmark uncertaints men these two cases are slight, since the diy and since the errors are only plotted proximately 2 minutes after the measurement of the covered and a sirily details to a second and	The repid error growth after each measurement is stylenary model utilized and also due to large ers. Two sets of runs were completed utilizing 100 in lainties and 10 meter landmark uncertainties. The men these two cases are slight, since the new get div and since the errors are only platted at fixed reximately 2 minutes after the measurement is made. Overall Program Description Latroduction This memorandum presents a fairly detailed minute covalidation seconds and since the covalidation program should thing Crief.	The repid error growth after each measurement is due to the stay anomaly model utilized and also due to large schalengers. Two sets of runs were completed utilizing 100 in landmark interestanties and 10 meter landmark uncertainties. The difference wen these two cases are slight, since the new set errors gradily and since the errors are only plotted at time interesting reximately 2 minutes after the measurement is made).	

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• Propageta error-coverience metrix.

- e Calculate measurement. Entrices. for a given measurement tolling at selected times of aviduals.
- o Perform measurement update of error-coverience matrix established least-squares Kalman filter algorithm.
- . Derive outputs of interest from error-coveriance bearin.
- . Iterate the above stars, according to a uner-dutinos and dis-

the first requires a calculation of specific-force time bisman, and requires calculation of newigational reference locations in teaction in teaction.

1.2 Program Inputs

The main input quantities to the program are the following:

- Trajectory time-history and related information (including
- The the Contention to an anti-
 - · Numerical values for personals in the 150 artis (See the test of the test of

Specific of a mission will be reclied.

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1.3. Program Ordana

The program of 11 print the position, velocity and 61 means (600 veloce) at verieus points along the trajectory, stands and fine lead to trajectory, at any second least level, and finight-peak continues frames.

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services a deal of reals to evide elected at another a

The filest is a prein Floure 1.1.

* Probagge error-covertance matrix.

• Calculate measurement metrices for a given measurement schame

Executive Program | 8304/92 56

* Partora measurement use to PRINCESS AINTEN BORSINSVOOT least-remarks Kalmer filter alguer than

Corive outputs of interest from error-covariance man

court of the desired

notacill todatos these steps contemptather we prove the centrality regulars calculation of rayinational reference

1.2 Program inputs

Elgune 1.1. Architecture Schemetic also met

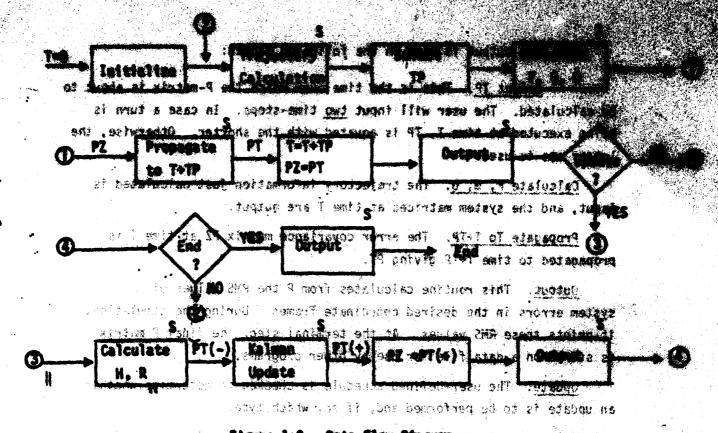
ribulan kun inganil kanala das yastetak sata yastesta 💌

An executive or bookkeeping program 15 shows Tills program decides (from ruser fuputs) on the order of plants and each to it that the various subcoutings are executed in the corresponding order. It also allows for omitting a given phases. (This will occur, for instance, if a finaltakeoff-coveriance, stored on a file, is to replace a fresh takeoffaimulation). Any other bookkeeping related to the owerell phasing structure of a mission will be included. The bound in Figure 1.1 do not necessarily represent superste polyment washered by the eliminations will entities and in the projugary calculations are also as

The second diagram in hestratus that suck-flow-indowned to any It is shown in Figure 1.2.

1.3 Program Outputs

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Calculate H. R. empaid and heated a . Astronomic version of location, and an indication of the type of measurement version of the type of measurement versions and remark matrices P and P. Internedicts columns to the and velocity of languages in inertial space such as the remark of the columns of the colum

In Figure 1.2, each block with an "S" above it represent appreciate subrouting. The other blocks represent appreciations by the property the individual blocks will be springly opened them.

to subroutions is initializate. The prof. Initialization of the profession of the pr

Irelectory Calculation. The main inputs are time and sylling to indicate phase. The outputs are:

- . position, velocity, specific force in impressi
- See an entire tion for the see that the second of the contract of the contract
 - all the coordinate transformation was
 - e a flee indication whether a shorp turn is being their

The less output Is subtline the following the subtline to the

Propagate To T+TP. The error covariance materix PZ at time T is propagated to time T+TP giving PT.

Output. This routine calculates from P the RMS maines of system errors in the desired coordinate frames. During the simulation, it prints these RMS values. At the terminal step, the final P matrix is stored on a data file for use by other programs.

Update. The user-defined schedule is checked to determine whether an update is to be performed and, if so, which type.

Calculate H. R. The inputs to this subrouting include time, location, and an indication of the type of measurement employed (e.g. star-tracker, landmark, bearing measurement, etc.). The outputs are the measurement matrices H and R. Intermediate calculations, such as position and velocity of landmarks in inertial space, must be made in order to calculate these outputs.

<u>Milian Bodita</u>. The error covertance metrix: ## is updated matrix: ##(+): The age tent and measurement matrices are input.

It repairs to give a methodistical discription of which is involved in each of the stope just mentioned. This is the best delicity of talking

Trajectory Calculation. The machinerate are that against we

indicate phase. The outputs ere:

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The main motivation for this is the later party with an execution in the second section in the second section in the second section is the second section in the second section in the second section is the second section in the second section in the second section is the second section in the second section in the second section is the second section in the second section in the second section is the second section in the second section in the second section is the second section in the second section in the second section is the second section in the second section in the second section is the second section in the second section in the second section is the second section in the second section in the second section is the second section in the second section in the second section is the second section in the second section in the second section is the second section in the second section in the second section is the second section in the second section in the second section is the second section in the section is the second section in the second section in the second section is the second section in the second section in the second section is the second section in the second section in the second section is the second section in the second section in the second section is the second section in the second section in the second section is the second section in the second section in the second section is the second section in the second section in the second section is the second section in the second section in the second section is the second section in the second section in the second section is the second section in the second section in the second section is the second section in the second section in the second section is the second section in the second section in the second section is the second section in the second section in the second section is the second section in the section is the second section in the section is the section in the section is the section in the section is the section in the secti

table of application and description of the standard of the st

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and find feeting weather a courp turn is being executed.

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the mostly memorytion employed in this memoryayus is that system errors

The purpose of Section 2 is to present a manufacture. describes the propagation of egrors, through the guidance title equations are presented explicitly only for some components of the such as the system matrices, Henry segments are handled more references to other literature which provides the details. Also, savered parts of the model are given only in preliminary form, and are the bearing raffin (see Section 3). motory sists (anotanomib-n = (1))

The order of presentation of the model does not follow the flow of the logic in Figure 1.2. (Rether, the most hature) mathematical order was chosen). Therefore, the following list of correlations between Figure 1.2 and the subsections of Section 2 with be helpful to the mader:

Initialize: Section 2.4.5

Trajectory Calculation: Section 2.5

Calculate F.G.Q: Section 2.4.3

Propagate to T+TP: Section 2.3

Output: Section 2.6

Calculate H.R: Section 2.4.4

Kalman Update: Section 2.3

Throughout this section; an error quantity is described as the computed (or observed) value minus the true value of the quantity. All of these errors are considered as rendom variables, and therefore, (since they are time dependent) as stochastic processes. . **E**[v(t_s) v (t_st)v]3 .

mit ... inere denoces the a-th component seed a

2.2 Linear Error Model Equations

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The basic assumption employed in this manorage is

can be represented mathematically in the form

describes the propagations of grors through the suddance system. Setable equations are propagations are proceeded explicitly only for some temponents of the much as the system matrices. Many segments are happined when generally we references to other literature which provides the letable. Many several parts of the model are given only in praisingly form, and are remember.

x(t) = n-dimensional state vector (8 noitoe2 ear)

 $\tilde{\mathbf{w}}(\mathbf{t}) = \mathbf{m}$ -dimensional continuous white-noise forcing vector

i(t) - C-dimensional measurement (or observation, or output)
vector, available at certain discrete times tot

"V(t.)" E-dimensional measurement action vectors

F(t), G(t), and H4 are real matrices of appropriate dimensions.

The noise statistics associated with the above system are given by the following equations:

 $\begin{aligned} & \tilde{\mathbf{E}}[\bar{\mathbf{x}}(t)] = \tilde{\mathbf{E}}[\bar{\mathbf{v}}(t)] = 0 & \tilde{\mathbf{E}}[\bar{\mathbf{x}}(t)] = 0 \\ & \tilde{\mathbf{E}}[\mathbf{x}^{\alpha}(t)] = 0 & \tilde{\mathbf{E}}[\mathbf{x}^{\alpha}(t)] = 0 \\ & \tilde{\mathbf{E}}[\mathbf{x}^{\alpha}(t)] = 0 & \tilde{\mathbf{E}}[\bar{\mathbf{x}}(t)] = 0 & \tilde{\mathbf{E}}[\bar{\mathbf{v}}(t)] = 0 \\ & \tilde{\mathbf{E}}[\bar{\mathbf{w}}(t)] = 0 & \tilde{\mathbf{E}}[\bar{\mathbf{v}}(t)] = 0 & \tilde{\mathbf{E}}[\bar{\mathbf{v}}(t)] = 0 \\ & \tilde{\mathbf{E}}[\bar{\mathbf{w}}(t)] = 0 & \tilde{\mathbf{E}}[\bar{\mathbf{v}}(t)] = 0 & \tilde{\mathbf{E}}[\bar{\mathbf{v}}(t)] = 0 \end{aligned}$ $\begin{aligned} & \tilde{\mathbf{E}}[\bar{\mathbf{v}}(t)] = 0 & \tilde{\mathbf{E}}[\bar{\mathbf{v}}(t)] = 0 & \tilde{\mathbf{E}}[\bar{\mathbf{v}}(t)] = 0 \\ & \tilde{\mathbf{E}}[\bar{\mathbf{v}}(t)] = 0 & \tilde{\mathbf{E}}[\bar{\mathbf{v}}(t)] = 0 \end{aligned}$

Note: χ^{α} here denotes the α -th component of the vector $\tilde{\mathbf{x}}$.

and interior is a solution of the solution of a solution o

$$\ddot{y}_{e}(t) = H_{e}\ddot{x}_{e}(t) + \ddot{v}_{e}(t)$$

where

where a discretized form of the math at the artificial armits are incepted as

where $v_{\rm g}(t)$ and $v_{\rm g}(t)$ are stationary continuous white-noise processes. In most cases, a model of this form arises naturally, but in others (the main example is gravity anomaly) another form of model (e.g. colored-noise forced) arises more naturally. In these latter cases, an approximating white-noise forced model must be derived.

2.3 Coverience Calculation (Propagate And Update P)

the information about error states provided by external measurements is incorporated by means of a Kalman filter. This procedure allows for a calculation in the navigation computer, of a running estimate \$(T) of the error state mector \$\bar{x}(t)\$, which is used to correct the indications of position, velocity, and attitude provided by the inertial navigator. The actual equations used will not be repeated here: rather we refer to Chapter 4 of Applied Optimal Estimation ed. by A. Galb (Ref. 2) perticularly to the tables on Page 110 and 123.* Mention should be used of the fact that the Kalman-filter assumption is an idealization since such an algorithm would be too unwieldy for INU computers. However, the assumption is above by the fact that the fact that the tables the weighting of measurements is done in actual systems in a way which is intended to approach actimality within realistic computational constraints

In stillying the propagation of brivers through the quitonce against via coveriance analysis; one is discovered in the time evolution of characteristics of the section of the section with the time of the section of t

 $\ddot{x}(z) = \ddot{x}(z) - \ddot{x}(z)$

Let

P(t) - E[M(t)K*(t)] +t

discrete, so that both tables apply

C 144 24 184 184

Their it was be show that between mean country and it is a still fair Masset differential management of the following malaman fall and the second of the sec THE PARTY OF THE PRESTORE OF THE PARTY OF TH and ode at (Alternatively, the propogation of P(t) can be represented by in di P(t+At) -0 P(t)0 +0k (1), x, H = (3), V

where a discretized form of the process is analoyed). The update of the covariance is given by omiter grammater on a (1) w bes (1) v broke

where K, is the Kalman gain metrix. All of these carculations are presented NOAMS have a not bir gleatural who hearth in full detail in Ref. 2. nevirse et tam lebon bestat

Of course, the calculation of P(t) using the equations presented above can only be accompished if the system and measurement matrixes are known. These stagues fare addressed in Section 2.42 the week of Abin, reserve stags

2.4 Quidance Error Model Description of hold to a season of hebancement

The preceding section discussed error covariance propagation in linear systems in general. The guidence subsystem error model (including the mode) for gravity anomalies which effect it) is a linear system of the form described in Section 2.2. Before the specific characteristics and dyallics of the guidance subsystem error model are described, it is convenient to introduce the coordinate frames in which the quantities of interest are defined " ntrest 33

2.4.1 Coordinate Frames

In this section, the coordinate frames to be used by the program are described. The three exes of each of these frames form a right-handle set. and their erisin is the center of the earth-outlots that payers) of these frame are fixed to inertial space, and others are not. Must of Mana fr are described in Britting's book (Ref. 1). He will will the designate the beginning of a mission.

 $\hat{x}(z) = \hat{x}(t)$

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The This was with the

ANT SOMETING A SAME STA in establishment control in appropria

- (1). Inertial Equatorial Frame (1-frame). This we the frame in which the trajectory position, velocity, and specific forces will be what well as ephaneris data for measurement beacons or landmarks and reflectors or a line in the equatorial plane with x through the Greenwich meridian at the The z axis points to the North Pole. The frame is inertial.
- (2). Earth-Frame (e-frame). This frame coincides with the i-frame at t=0 but is fixed relative to the earth. Thus, it retates about z^{1} at rate x^{2} .
- (3). Geographic frame (n-frame). This frame has its axes aligned with north, east and down directions at the present location (time t) of the vehicle. It is a natural frame in which to express the rms output errors. This frame rotates with the earth and the vehicle.
- (4). Flight-path* frame (t-frame). This frame is used to specify gravity models. The geographic frame is rotated about the z axis, so that the x axis points in the vehicle direction of flight. Thus, the x^t and y^t axes form an along/cross track reference system.
- (5). Platform-frame (p-frame). This frame is a natural one for specifying the errors in inertial instruments. The axes are the output axes of the accelerometers, with the x^p , y^p axes parallel to the platform.

2.4.2 System State Vector

This section presents the physical meaning of the elements of the state vector $\vec{x}(t)$ in the linear error model equation. The basic form of the 62-dimensional vector is

$$\bar{x}^{-}(t) = [\bar{\delta r}^{-}(t), \bar{\delta v}^{-}(t), \bar{\psi}^{-}(t), \bar{d}^{-}(t), \bar{x}_{G}(t), \bar{x}_{G}(t), \bar{x}_{G}(t), \bar{x}_{G}(t)]$$

In this equation, δr and δv are 3-dimensional position and velocity errors in the i-frame, and ψ is the 3-dimensional platform misalignment (attitude) error vector, coordinatized in the i-frame.

The following paragraphs describe gyro and accelerometer errors. These errors are modelled in accordance with, and use the notation of, Ref. 3.

^{*}Also called the track frame, since it has along-track, cross-track and down axes.

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z earls points to the Morto Pole. The frene bias drift vector da Dax (2) Forth-From Te-frome dy = DTY e itt. of myitsier bezut gi ded imgres Unbalance Drift Error Coefficients $d_3 = D_{OX}$ de = DSX 2 238 MOORE \$ mar and seek size is grid been righted Cartifor to the state of the - DIIX a o in the long that animals being = D_{OOX} - D_{SSX} Hiance Drift Error Coefficients ka monion stvole - Diex ្រុក ខេត្ត ស្នា ១៩ភាព ខេត្ត ម<mark>ាក់</mark>ស្នាំ dag = DSIX

(In these equations, the symbols I, 0, and S refer the input-output-spin axes of the gyro). Similar definitions hold for d_{11} through d_{30} with all these drift biases assumed to be statistically independent.

The 15-dimensional vector $\tilde{\mathbf{a}}(t)$ represents the accelerometer errors. The input axes of the three accelerometers are along the platform $\mathbf{X}_{t}\mathbf{Y}_{t}\mathbf{Z}$ axes respectively. The first 4 elements of $\tilde{\mathbf{a}}(t)$ are defined as follows:

a₁ = K_X = bias error

a₂ = K_{IX} = scale-factor error coefficient

a₃ = K_{IIX} = scale-factor non-linearity coefficient

a₄ = K_{CAX} = cross-axis non-linearity coefficient

Elements 5 through 12 of a are similarly defined with reference to the Y and Z accelerometers. Elements 13 through 15 represent mounting misalignment errors as follows:

11

2.4.3 System Metrices (F. 3. 1)

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where of - misalignment angle from 1-th to j-th existing

The three dimensional vector $\mathbf{x}_{\mathbf{G}}$ represents the gravity anomaly errors, referred to f-trams coordinates. Specifically,

 x_{GI} = along-track vertical deflection

xe2. - cross-track vertical deflection to he appeared by

 x_{G3} = anomaly magnitude/ g_N ,

where g_N = average surface gravity. (The scaling of the latter by g is merely a convenience).

The remaining states refer to the altitude damping based on altimeter measurements. Third order damping is assumed (as in Ref. 4), and this gives rise to three damping states, one for each i-frame axis. The three-dimensional vector $\bar{\mathbf{x}}_{A}(t)$ represents these states. (The 6a notation of Ref. 4 is not used to avoid confusion with accelerometer errors). The two-dimensional vector $6\bar{\mathbf{h}}_{\text{tef}}$ represents altimeter errors, and is defined as

Sh_{ref 1} = 1st order Markov error

Sh_{ref 2} = bias error

This completes the description of the error-state vector.

2.4.3 System Matrices (F, G. Q)

130 = 81

The system matrices describe the fundamental among dynamics of the INU.

The matrices defined here are based on three sources of information:

Space-stable IMU dynamics (Ref. 1)

Third-order altitude damping (Ref. 14) 27 1 200 0 . . . 2 2000 A

Inertial-instrument error models (Ref. 3)

The reader of this memorandum desiring detailed interpretation of the system matrices should refer to these sources.

The dynamics matrix F(t) has dimension 62 by 62, in accordance with the dimension of the error-state vector $\tilde{x}(t)$. F(t) is presented in partitioned form as:

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specific ferrom acting at the court of the

 $I_3 = 3$ by 3 identity

Olxj = 1 by j matrix of O's descriptions on tomb a it ga symbol

to altitude demping. Let

$$\bar{u}_{R} = \frac{\bar{R}^{1}(t)}{|\bar{R}^{1}(t)|}$$

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where $R^i(t)$ is i-frame position. (These quantities will be used frequently in subsequent equations). Then

where k_{\parallel} is a damping coefficient. $F_{\parallel,\parallel}(t)$ is 3 by 2, representing the effect of altimeter errors. The definition is

 $F_{1,8}(t) = k_1[\bar{u}_R : \bar{u}_R].$

(The colon signifies justaposition of matrices).

 $F_{2,1}(t)$ is 3 by 3, and is defined as

$$F_{2,1}(t) = F_{2,1}^{s}(t) + F_{2,1}^{0}(t)$$

 $F_{2,1}^{S}$ (t) reflects Schuler dynamics, and is

$$F_{2,1}^{s}(t) = \frac{3\omega^{2}_{s}(t)}{|R^{i}(t)|^{2}} R^{i}(t)R^{i}(t) - \omega^{2}_{s}(t)I_{3}$$

where wg(t) is the Schuler frequency:

$$w_{s}^{2}(t) = \frac{C_{g}}{|\vec{R}^{1}(t)|^{2}}$$
 $C_{g} = 4.84814 \times 10^{-6} \text{ red/sec}$

In = 3 by 3 identity

where k2 is a demping coefficient. The kinds and a second of the contract of t

The $F_{2,3}(t)$ matrix is 3 by 3, and models who imminished acceleration caused by platform alignment errors. We design to by $F_1(t)$ the specific force acting on the instruments. Then

$$F_{2,3}(t) = \begin{bmatrix} 0 & -f_3^1(t) & f_2^1(t) \\ f_3^1(t) & 0 & -f_1^1(t) \\ -f_2^1(t) & f_3^1(t) & 0 \end{bmatrix}$$

The matrix $F_{2,5}(t)$ is 3 by 15. This matrix models the acceleration indication errors (bias, g-sensitive, etc). (For further explanation, see Ref. 3). To describe this matrix, we let

$$7^{p}(t) = C_1^{p} 7^{1}(t)$$

where C_i^p is the transformation from the i to the p frame. (This will be a program input representing nominal platform orientation). Then dropping the t's for convenience:

ends into platform subligaments. (Further explanation of the process of the process of the process of the chief the chief the process of the chief the chief

 $(r_{2}^{p})^{2}+(r_{2}^{p})^{2}=0$ r_{1}^{p} r_{2}^{p}

The matrix $F_{2,6}(t)$ reflects the affect of gravity anomaly on system errors. It is given by:

$$F_{2,6}(4) = g_N c_t^1$$

where g_N is average gravity at sea-level. Note that the t to i transformation is time-varying. It will be provided by trajectory calculations.

 $F_{2,7}(t)$ is 3 by 3, and is part of the altitude demping dynamics. It is simply

$$F_{2,7}(t) = -I_{3x3}$$

 $F_{2,8}(t)$ is 2 by 3, reflecting the effect of altimeter errors. It is defined by

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$$F_{2,8}(t) = k_2[\bar{u}_R : \bar{u}_R]$$

where k_2 is a damping coefficient.

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to the warding. It will be provided by trajectory calculations

In these equations TP is defined as earlier in this sacking. Type

in which the FG1's and 0's are all 12 by 16 metricing and for 1-1,2,3

IN note that rows 10 through 54 of the f(t) matrix are compared of 8's. This reflects the fact that all of the instrument error can are treated as random constants—that is, in the absorbe of an extension they do not deviate from their original (t=0) values.

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O THE MONA" YARDAS " EE" where Agray is defined above (For (t)), and Quest the vertical deflection standard deviation and Jakon is the angually (magnitude) standard deviation." FREE PALT CALLERY.

we have fully to the inverse correlationation of the gods), which is gain 's the standard deviation of this same error.

The Constitute to see by a, and their contents of the profession of the unavitar and altimater error models. . Ple defined is malined

with V_q = ground speed, D_q = characteristic distance of gravity enough field.

F7.1(t) is 3 by 3 and is another altitude damping term. It is

 $F_{7.1}(t) = k_3 U$

where kg is a desping coefficient.

F7.8(t) is 3 by 2, reflecting effect of eltimeter errors.

contract correspondentation de care de des de constataciones est recontraciones electrones It is to be rected that the various ased is computing whese selections are F7.8(t) = -k3[uR : uR]

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Coordinate transformation materiors ...

These values are all sent ble for user thout and the others from the frosectors

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where β_{GRAV} is defined above $(F_{6,6}(t))$, and σ_{VD} is the vertical deflection standard deviation and σ_{ANCM} is the anomaly (magnitude) standard deviation."

944 = 28ALT GALT-M2

where β_{ALT} is the time constant of the altimeter Merkov error, and σ_{ALT-N} is the standard deviation of this same error.

The 6 matrix is 62 by 4, and inputs the white driving noise into the gravity and altimeter error models. It is defined as follows:

0_{54x4}
I₃: 0_{3x1}
0_{3x4}
[0 0 0 1]

This completes the description of all of the error model system matrices. It is to be noted that the variables used in computing these matrices are: ,

- . Numerical parameters for instrument, and gravitational error models:
- . Position and specific force in inertial spaces
- · Coordinate transformation matrices.

These values are all available from the program, the first group from user input and the others from the trajectory calculations.

*Units: ovo angular, oamon acceleration.

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off, 1.1.2....18 and input. For example, of delist the common standard

2.4.4 Measurement Matrices (H,R)

The CBH program utilizes two fundamental classes of external updates.

For the tactical application a bearing measurement to knew landmarks has been added to the CBM program. He note that the calculations require the following inputs:

- Prostition and velocity in Turismen was to the appropriate at the end
- . Time into mission, to calculate i-frame location of land stations

erescopes. Thes day no

· Standard deviation of update-station ephemeris errors.

2.4.5 Initial Covariance Matrix

In solving the Ricatti differential equation (Section 2.3.1) for P(t) a value of P(0) is required. This represents the covariance matrix of errors states prior to takeoff.*

However, the P(0) is itself a result of the errors in complex initial calibration and alignment procedure. The actual P(0) matrix will depend heavily on the particular mechanization of this procedure, on the time alloted to the procedure, and other factors. At the time of this writing, study in this area is still in progress. This section presents a simplified model, based on the assumption of uncorrelated error-states.**

P(0) is assumed diagonal, with P_i denoting the 1-th diagonal element. The first 9 of these are

$$P_* = 0$$
 1=1 through 6

$$P_1 = [\sigma(\psi_0)]^2 1 = 7.8.9$$

where $\sigma(\psi_0)$ is the rms initial alignment error per axis. The next 30 terms are defined in terms of standard deviations of the gyro errors d_1 , 1=1,2,...30 listed in Section 2.4.2. It is assumed that these standard deviations are the same for all three gyroscopes, so that only ten standard deviations,

^{*} The value of P(t) at the beginning of the loiter and phase is simply the terminal value from the preceding phase.

^{**}For a gimbal-memory alignment system this assumption is fairly realistic.

 $\sigma(d_1)$, i=1,2,...10 are input. For example, $\sigma(d_5)$ is the common standard deviation of the compliance drift error coefficient D_{11} for the three gyroscopes. Then define

The next 15 diagonal elements represent accelerometer errors. The accelerometer standard deviations are given as $\sigma(a_4)$, i=1,2,3,4 and $\sigma(\delta)$, where δ is the mounting error misalignment. Then define

$$P_{39+1} = P_{43+1} = P_{47+1} = [\sigma(a_1)]^2,$$
 $i = 1,2,3,4$

$$P_{52} = P_{53} = P_{54} = [\sigma(\delta)]^2$$
.

The next three (gravity anomalies) are

P₅₅ = P₅₆ =
$$\sigma_{VD}^2$$

$$P_{57} = (\sigma_{ANOM}/g_N)^2$$

σ_{vn} = standard deviation of vertical deflection

GANGE - standard deviation of gravity anomaly

g_N = nominal gravity

Corresponding to the damping states,

Finally, the altimeter errors are initialized by

11

This completes the description of the initial F metrix.

2.5 Trejectory Calculations

Namy of the calculations to the other sections togetherly 2.4.3.

2.4.4, and 2.4.6) require current trajectory-related information. The list of required data, at any given time to is:

Ri - i-frame position

Vi = i-frame velocity

7 - 1-frame specific force

v_a = ground speed

 $C_n^{\dagger}, C_+^{\dagger} = \text{direction cosine-matrices}$

The equations for calculating these are not reproduced here. Obviously they will be different for the several phases of a mission.

The loiter-phase trajectory includes some segments with sharp turns, where system-dynamics vary, and some long straight segments, where they are stable. Therefore a flag will be output to indicate, for the given time, which of these segment types the missile is located on. Such a flag will not be required for the other phases.

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2.6 Output Calculations

Malia Dial Yearsol St. There are two classes of output of interest. The first is the standard deviation of major INU errors, presented as a function of time. The second is the complete covariance matrix at the end of the phase, which is to be used to initialize the succeeding phase.

The IMU errors of interest are position, velocity and alignment errors coordinatized in the 1 and n-frames. (Velocity is with respect to inertial space, regardless of the frame it is coordinatized in). Partition the P matrix at time T as

in which all the sub-matrices are 3x3, and the spaces are not of interest

$$\sigma(\delta r_{\alpha}^{i}) = P_{R}(\alpha,\alpha) , \alpha=1,2,3$$

$$\sigma(\delta V_{\alpha}^{i}) = P_{V}(\alpha,\alpha) , \alpha=1,2,3$$

$$\sigma(\psi_{\alpha}^{i}) = P_{\mu}(\alpha,\alpha) , \alpha=1,2,3$$

wher \mathbb{R}^{1} , $\overline{\delta V}^{1}$, $\overline{\psi}^{1}$ are i-frame IMU errors. Next calculate

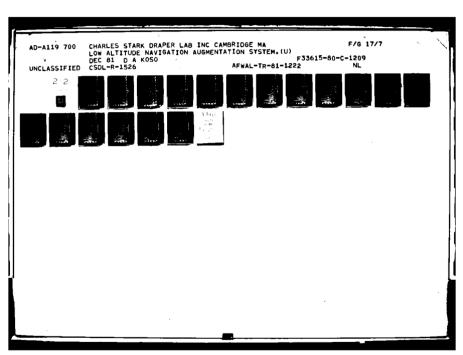
$$P_{R}^{n} = C_{1}^{n} P_{R} C_{n}^{1}$$
 $P_{V}^{n} = C_{1}^{n} P_{V} C_{n}^{1}$
 $P_{L}^{n} = C_{1}^{n} P_{L} C_{n}^{1}$

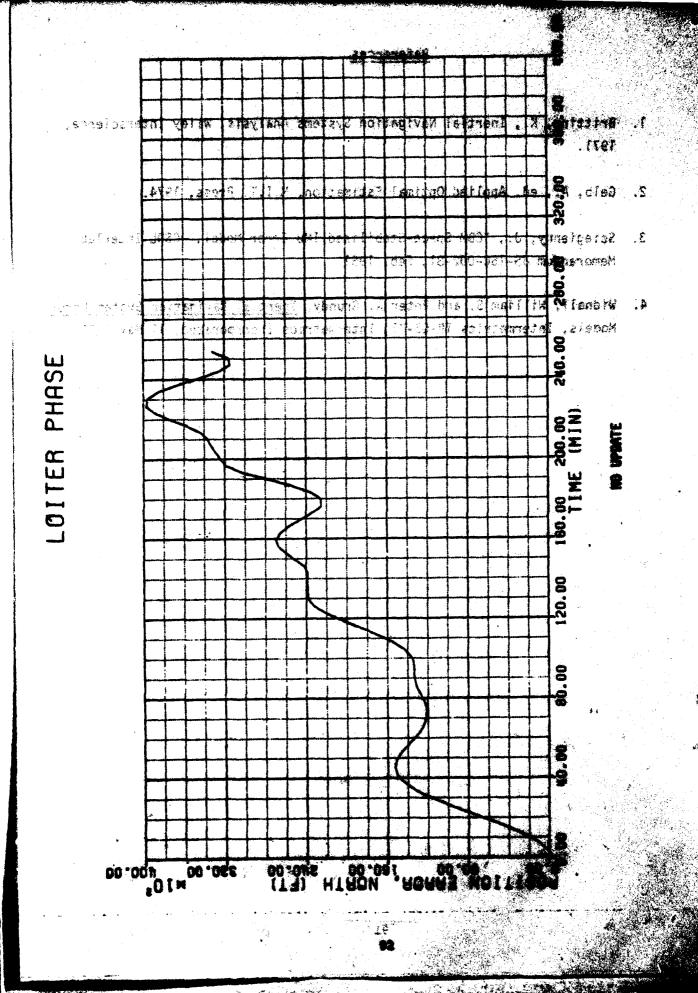
Then the n-frame outputs may be calculated from these matrices just as in the case of the i-frame outputs. Both sets of standard deviations may be calculated continously in time from the current P(t) matrix.

The second output is simply the entire P matrix at the end of and requires no further discussion.

References

- 1. Britting, K., Inertial Navigation Systems Analysis, Wiley Interscience, 1971.
- 2. Gelb, A., ed. Applied Optimal Estimation, M.I.T. Press, 1974.
- 3. Sciegienny, J., "CBM Space-Stabilized IMU Error Model," CSDL Interlab Memorandum JS-15C-002-81, Feb. 1981
- 4. Widnall, William S. and Peter A. Grundy, <u>Inertial Navigation System Error</u>
 Models, Intermetrics TR-03-73, Intermetrics Incorporated, 11 May 1973.

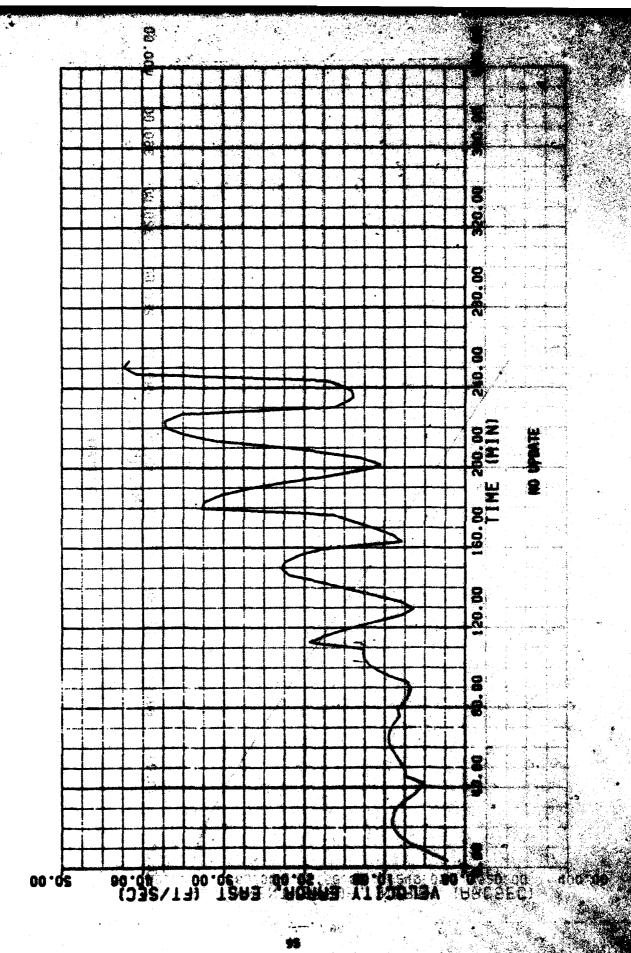




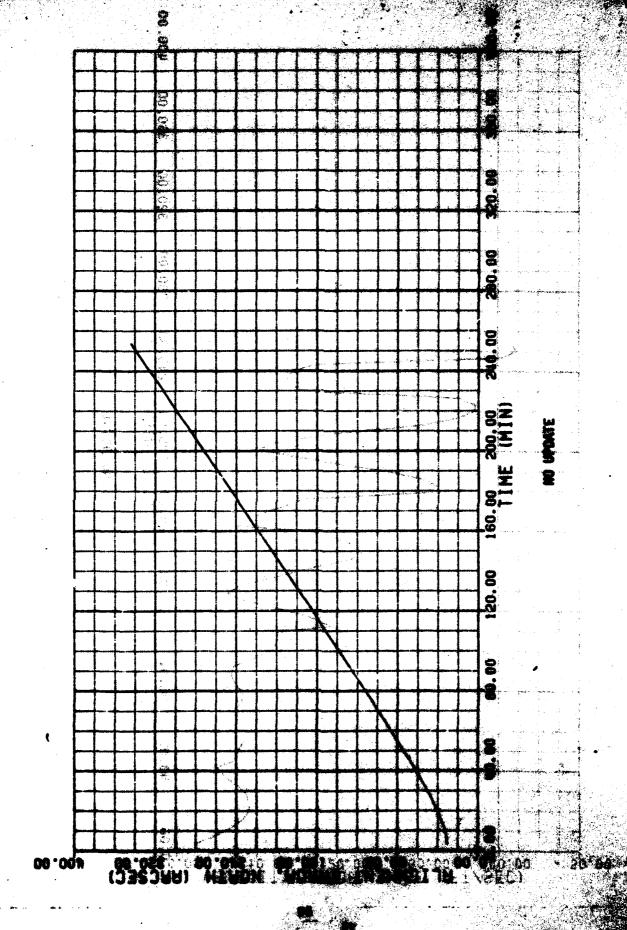
LOITER PHASE

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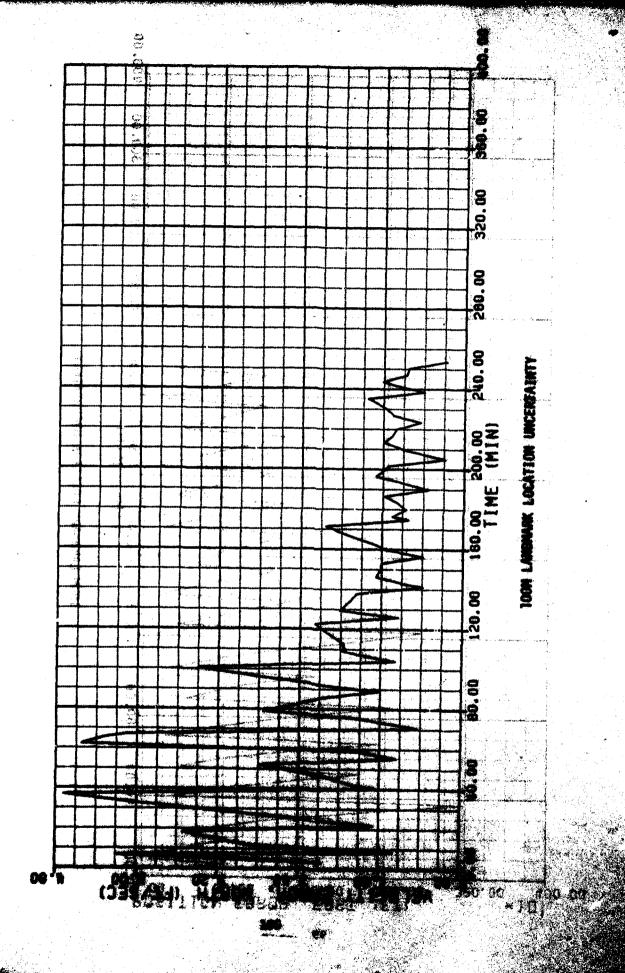


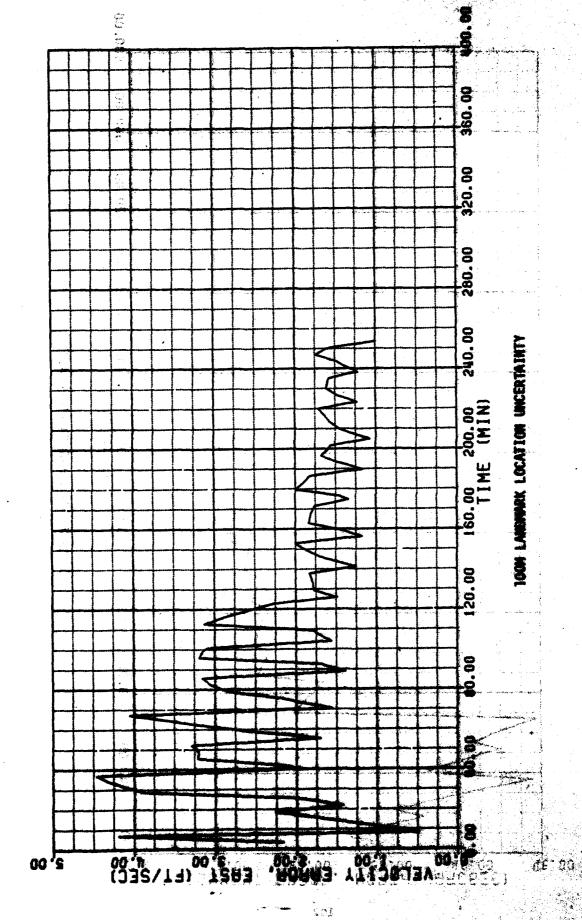
JOHNA RATIO

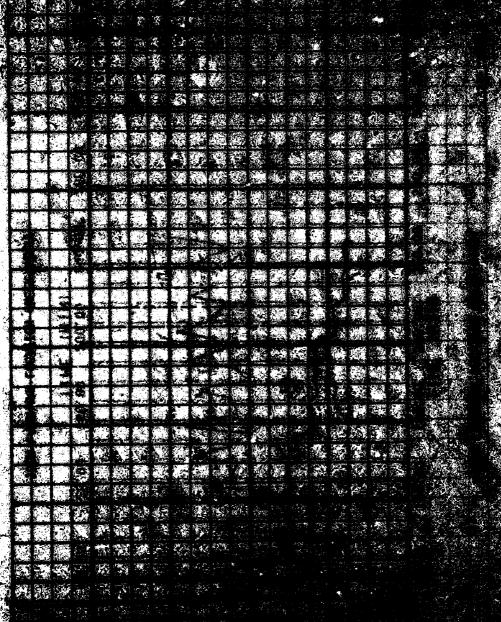
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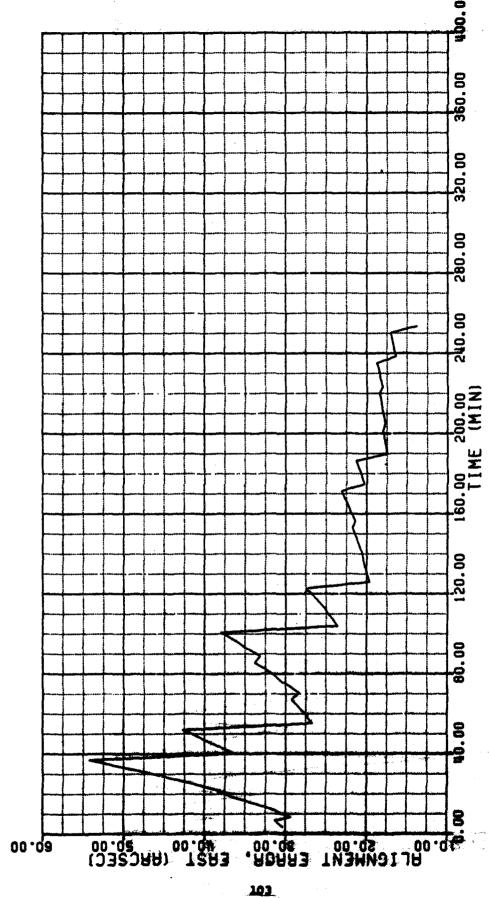
LOITER PHASE

FOLLER SHUZE

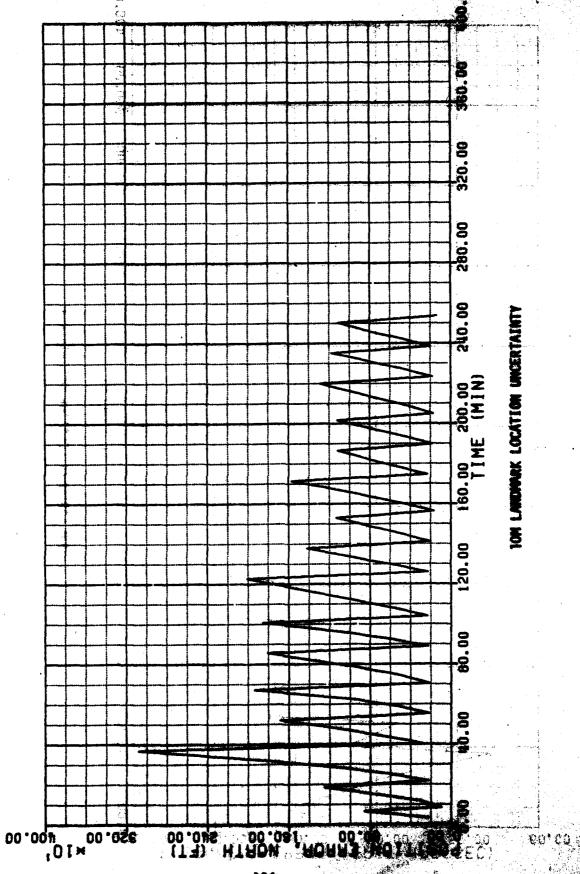


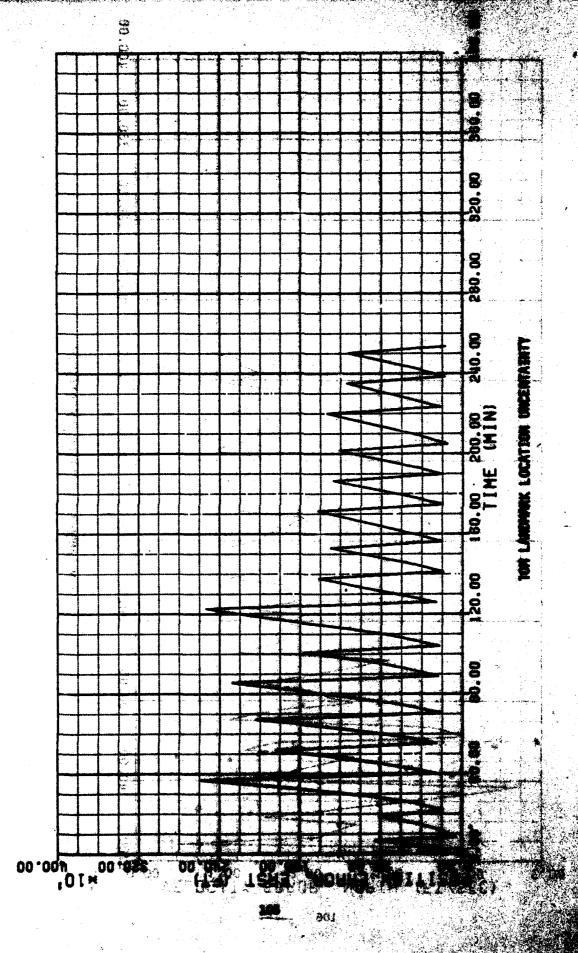


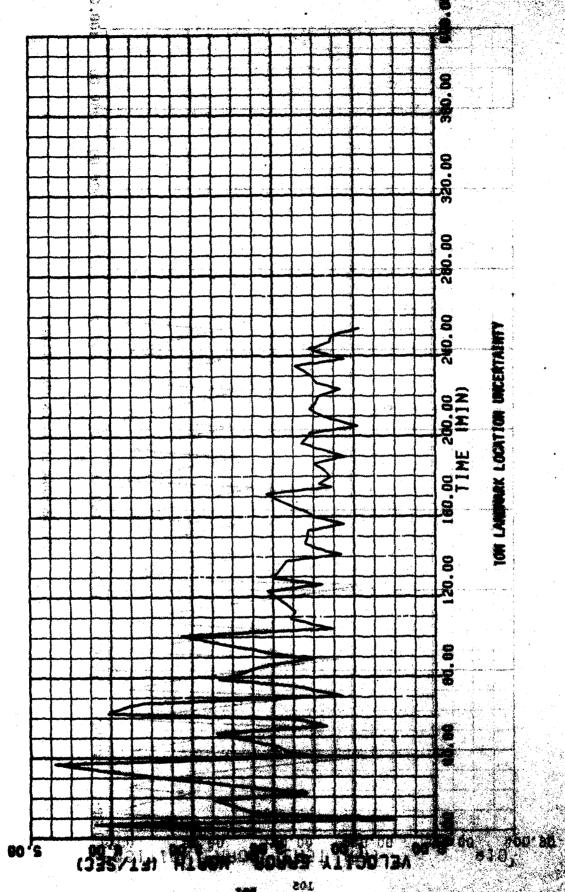


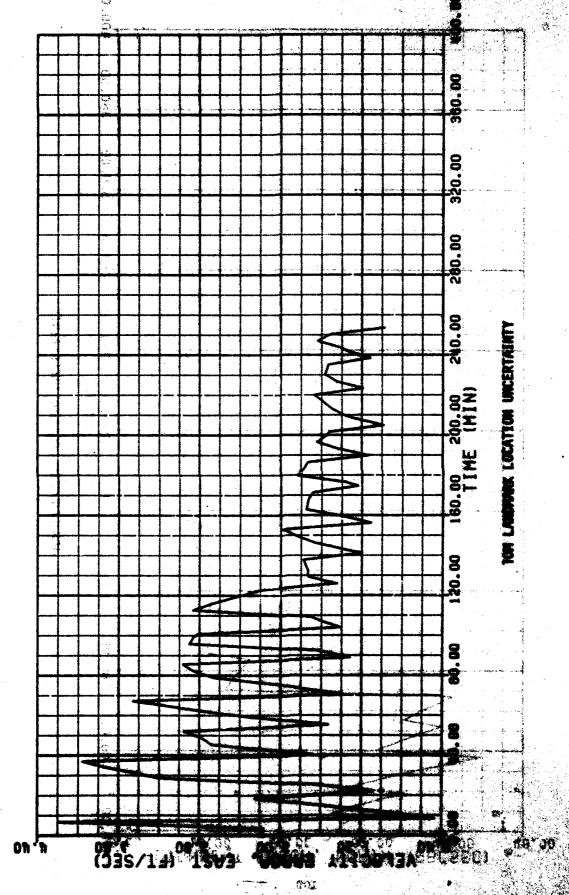


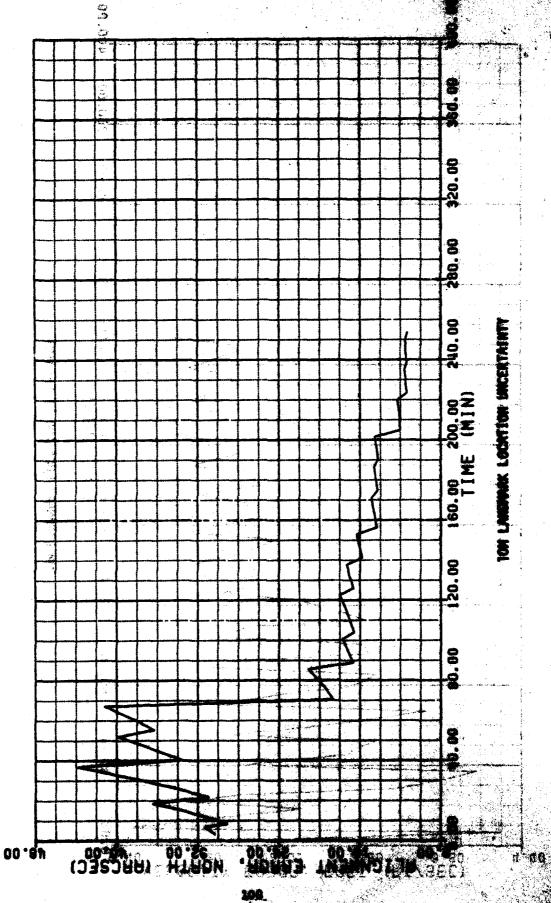
100M LANDWARK LOCATION UNCERTAINTY

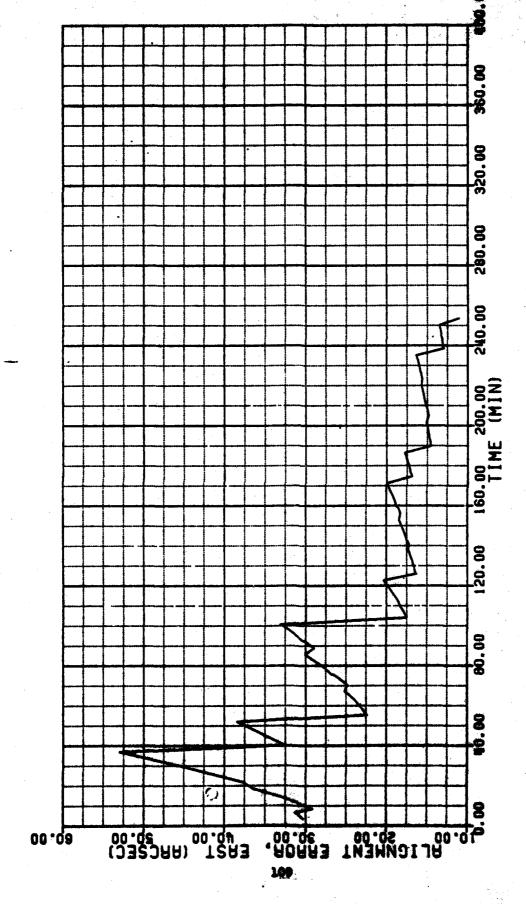












109 LANDBARK LOCATION UNCERTAINTY

